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(54) **A hydrogenation catalyst for use in a hydrogen peroxide process, and a method for the preparation thereof**

Hydrierungskatalysator, Verfahren zur Herstellung dieses Katalysators und seine Verwendung bei der Herstellung von Wasserstoffperoxid

Catalyseur d'hydrogénation pour la production du peroxyde d'hydrogène et procédé pour le préparer

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**EP 0 611 126 B1**

## Description

The invention relates to a hydrogenation catalyst for use in the production of hydrogen peroxide, the catalyst mainly containing noble metal, of which more than 50 % is palladium, to a method for the preparation of the catalyst, and to a hydrogenation process, based on the use of the catalyst, as part of a hydrogen production process.

In the production of hydrogen peroxide by the anthraquinone process, hydrogenation, oxidation and extraction stages succeed one another. Anthraquinone, or a derivative thereof, dissolved in organic solvents is hydrogenated in the presence of a catalyst to the corresponding hydroquinone. The hydroquinone is oxidized with oxygen, whereupon it regenerates to its prehydrogenation form, and simultaneously hydrogen peroxide is formed. The formed hydrogen peroxide is removed by aqueous extraction. The anthraquinone is recycled to hydrogenation.

The catalyst used in the hydrogenation is in the main palladium. Palladium is used either as such or attached to various supports. The most commonly known supports are aluminum oxide, carbon, and silica gel. In supported catalysts the concentration of Pd may vary between 0.1 % and 10 %.

A Raney nickel catalyst has also been used in the preparation of hydrogen peroxide. The palladium catalyst has reduced the share of nickel catalyst in use.

Although the amount of catalyst is not decreased in the chemical reaction, the catalyst nevertheless loses part of its activity in use. Spent catalyst which has lost its activity can be reactivated by regeneration. In the regeneration of catalyst, organic solvents, acids/bases, are used, followed by water treatments, vaporizations, and possibly drying and thermal treatments.

A catalyst can be in part reactivated a few times by the treatments mentioned above. Finally, a stage is reached at which regeneration is no longer useful. At that time the noble metal is recovered from the catalyst and a new catalyst is prepared.

Efforts have been made to increase, by various means, catalyst activity and the retention time of the activity. To a silica gel supported catalyst there have been added, in addition to Pd, also zirconium, thorium, hafnium, cerium, titanium and aluminum as an oxide, hydroxide or carbonate (EP patent 009802 and US patent 4 521 531).

Alumina support has been impregnated with copper and silver compounds in addition to palladium. The metals have been reduced onto the support by a conventional method. The additive metals improve the selectivity of the catalyst in the preparation of hydrogen peroxide (JP patent 74 05 120).

It has been observed that a corroded alloy of nickel and aluminum, which additionally contains iron, chromium, molybdenum and copper, has catalytic properties in the hydrogenation of anthraquinone. It is claimed that the selectivity of the catalyst is high. It is used in the preparation of hydrogen peroxide (SU patent 931221).

The drawbacks of the catalysts with additives mentioned above include complicated regeneration, recovery of the noble metals, the use of a new support with impregnation, addition of additives, and reductions.

An object of the invention is to provide, for use in a hydrogen peroxide process, a hydrogenation catalyst which eliminates the deficiencies involved in the above-mentioned state-of-the-art catalysts. Thus the objective is to provide a catalyst the activity of which is high and which is durable. These requirements are fulfilled by the catalyst according to the invention. It is likewise an object of the invention to provide a method for the preparation of the catalyst and a process for the hydrogenation of anthraquinone or a derivative thereof, based on the use of the catalyst, as part of a process for the production hydrogen peroxide.

The characteristics of the invention are stated in Claims 1, 6, and 12.

By using a noble metal catalyst to which the addition according to the invention had been made, a multiplication of activity was, surprisingly, achieved as compared with a conventional noble metal catalyst without the additives. Furthermore, the catalyst according to the invention retains its activity for a longer period at a higher level than does a catalyst not containing the additives. The catalyst according to the invention has the further advantage that its regeneration requirement is lower than that of conventional hydrogenation catalysts.

Noble metals suitable for this purpose include metals of the platinum group (Pt, Pd, Rh, Ir, Os, Ru) and mixtures thereof. The form of the metal in the preparation of the catalyst is not decisive. They can be used in metallic form or in metallic ion form. Palladium and platinum are suitable noble metals. An active catalyst is obtained by using as the noble metal palladium or a combination of palladium and platinum. In the combination of palladium and platinum the amount of palladium is over 50 % by weight of the total amount of the noble metals.

Transition metals or aluminium are used as the additive. Iron, chromium and nickel are preferred transition metals. Other transition metals which can be used include zinc, copper, cobalt, manganese, vanadium, titanium, zirconium, cerium, and lanthanum.

The additive used may consist of one or several transition metals. In the preparation of the catalyst the transition metals may be used in the form of a metal, metal salt, or metal salt solution. The additive concentrations vary for each component within 0.01-3.0 %, calculated from the total noble metal amount.

The hydrogenation catalyst according to the invention is prepared by adding a transition metal to a noble metal catalyst of which more than fifty per cent is palladium. The adding of the transition metal to the noble metal takes place, for

example, by precipitation from a solution. Alternatively, it is possible to use, for example, methods based on impregnation. In addition, the transition metal can be precipitated at high temperatures by using conventional precipitation methods or, for example, the plasma technique.

The hydrogenation catalyst is prepared from a solution by dissolving in an acid a noble-metal containing catalyst of which more than fifty per cent is palladium and which may be in the form of either a salt or a metal. Noble metal in the form of a salt may be slurried in water before being dissolved in acid. One or more transition metal is added to the obtained acid solution. The transition metal may be as a metal, as a metal salt, or as a metal salt solution.

The temperature of the solution may vary between 10 and 100 °C. The solution is neutralized with an alkaline material, for example with soda lye or potassium lye.

The noble metal is reduced, at which time the transition metal is coprecipitated. After the precipitation the pH will be between 6.5 and 10. The catalyst is obtained in the precipitation in the form of finely-divided metal particles having a particle size within the range of 1-100 µm.

The catalyst is washed clean of the mother liquor by means of water. The washed catalyst may be dried or transferred to an organic solvent medium environment or into a working solution medium before being tested and used.

A noble metal, such as palladium, used in metal form may be previously used metal or unused. Palladium in salt form may be any palladium-containing salt, e.g. halide, nitrate, or sulfate. Likewise, the transition-metal salt may consist of any of the salts mentioned above, for example nitrates, halides and sulfates. It is also possible to use metallic transition metals.

Acids suitable for the dissolving of noble metals include strong acids, in particular hydrochloric acid and nitric acid.

The acid or the acid mixture is used in excess of the stoichiometric amount. In addition, hydrogen peroxide may be used, when necessary. The acid solution containing noble metal is diluted to a suitable concentration of 1-50 g/l before the adding of the transition metals. The transition metal components may be used in either the same proportion or in different proportions to the noble metal. The concentrations vary, for each component, within 0.01-3.0 %, calculated from the total noble-metal amount.

The reduction can be carried out by using a reducing agent suitable for the reduction of the noble metals, such as formaldehyde, formic acid, hydrogen, hydrazine, or sodium borohydride.

Hydrogenation catalysts according to a preferred embodiment are obtained by adding iron, chromium or nickel to palladium. It is also possible to use iron, chromium, or iron and nickel, or chromium and nickel. A particularly active hydrogenation catalyst is obtained when small concentrations of all of the three components are simultaneously mixed with the palladium.

The concentration range of the transition-metal components is limited separately for each metal component to 0.01-3.0 %. Beyond this concentration range the number of small particles will be too high. Additives even as such decrease and embrittle the palladium black particle, which in turn contributes to the increase of activity, but also small separate particles of transition-metal compounds cause a disadvantage both during the preparation according to the invention and during use.

The hydrogenation of anthraquinone or its derivatives is carried out by means of hydrogen or a hydrogen-containing gas in a working solution in which the finely-divided catalyst is suspended. As the solvent in the working solution it is possible to use organic solvents consisting of one or more components. Suitable solvents or suitable components of the solvent include aromatic hydrocarbons, which dissolve the anthraquinone, and more polar solvents, which retain the forming anthrahydroquinone in the solution. Suitable are, for example, secondary alcohols, trialkyl phosphates, 2,6-dialkylcyclohexanone, mono and diacetyl benzophenone and triacetyl benzenes, tetraalkyl urea compounds, amides and caprolactams.

In the following examples, catalyst activity was tested in a working solution containing 2-ethyl-anthraquinone 100 g/l and catalyst 0.5 g/l, in an organic solvent mixture made up of an aromatic hydrocarbon and organic phosphate. The testing was carried out in an autoclave under a pressure of three bar at a temperature of 50 °C, with a hydrogenation time of five minutes. The  $H_2O_2$  concentration was determined on the oxidized working solution.

#### Example 1

Palladium chloride (200 g) was dissolved in a 33-percent hydrochloric acid (250 ml), and the solution was diluted to 10 liters. Aqueous solutions containing metal components were prepared from  $FeCl_3 \cdot 6H_2O$ ,  $CrCl_3 \cdot 6H_2O$  and  $NiCl_2 \cdot 6H_2O$  salts. The metal component concentration in the solutions was 1 g/l. That the components remained in the solutions was ensured by means of a small addition of hydrochloric acid (2 ml/l 33 % HCl). 4.0 ml of an iron salt solution was added to 600 ml of the Pd solution. The pH of the solution was raised to approximately three by means of lye before the adding of formic acid, which was used as the reducing agent (1.5 x the stoichiometric amount in proportion to palladium). When the pH is increased with lye to approximately 9, the Pd is reduced and the additive metal is coprecipitated. The catalyst is prepared under a nitrogen shield gas. The catalyst is washed with water and is transferred from the aqueous medium to a working solution or to the solvent part of the working solution before the testing. The catalyst

was tested as described above. The hydrogen peroxide yield obtained by means of the catalyst under the testing conditions was 15.7 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 2

A catalyst was prepared in accordance with Example 1, except that no metal salt solution was added. The hydrogen peroxide yield obtained by means of the catalyst was 7.8 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 3

A catalyst was prepared as in Example 1, but the additive-metal component was not added in the form of a solution but as a solid salt. The salt used was FeCl<sub>2</sub> · 6H<sub>2</sub>O. 90.5 mg of ferrichloride was added per 600 ml of the Pd solution. The hydrogen peroxide yield obtained by means of the catalyst was 11.6 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 4

A palladium black catalyst (0.068 mol) which had been used for the hydrogenation of anthraquinone was slurried in water and was dissolved in 55 ml of a 33-percent hydrochloric acid. 7 ml of a 50-% hydrogen peroxide was used as an auxiliary in the dissolving. In other respects the catalyst was prepared as in Example 1. Iron, which was used as the additive metal, was added in the form of an iron chloride solution according to Example 1, in an amount of 39.9 ml. The hydrogen peroxide yield obtained by means of the catalyst was 10.1 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 5

A Pd catalyst (0.068 mol Pd) which had been used for the hydrogenation of anthraquinone was dissolved in 103 ml of a 30-percent HNO<sub>3</sub>. In other respects the preparation of the catalyst was as in Example 1, but the above solution was used instead of a Pd chloride solution, and iron was added in metal form in an amount of 52.5 mg. The hydrogen peroxide yield obtained by means of the catalyst prepared was 12.2 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 6

A palladium black catalyst was dissolved as in Example 4. The preparation was in other respects the same as in Example 1, but the reduction was carried out by means of formaldehyde (1.5 x the stoichiometric amount in proportion to palladium) instead of formic acid, and 2.2 ml of a chromium salt solution was added instead of the iron salt solution. The amount of chromium added must be 10 % more than the Cr concentration desired for the catalyst. The chromium salt solution was prepared in the manner according to Example 1. The hydrogen peroxide yield obtained by means of the catalyst was 12.9 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 7

A catalyst was prepared as in Example 1, but instead of an iron salt solution, 15.1 ml of a chromium salt solution was added to the solution. The hydrogen peroxide yield obtained by means of the catalyst was 13.3 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 8

A catalyst was prepared as in Example 7. The chromium salt solution was added in an amount of 20.6 ml. The hydrogen peroxide yield obtained by means of the catalyst was 13.3 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 9

A catalyst was prepared as in Example 4, but 22.1 mg of chromium metal instead of an iron salt was added to the solution; the chromium metal was allowed to dissolve in the hydrochloric acid solution before the subsequent stage. The hydrogen peroxide yield obtained by means of the catalyst was 12.0 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 10

A catalyst was prepared as in Example 1, but 0.8 ml of a nickel chloride solution instead of an iron salt solution was added to the solution. The hydrogen peroxide yield obtained by means of the catalyst was 11.8 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 11

A catalyst was prepared as in Example 10, but the nickel chloride solution was added in an amount of 2.0 ml instead of 0.8 ml. The hydrogen peroxide yield obtained by means of the catalyst was 11.4 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 12

A catalyst was prepared as in Example 11, but the nickel chloride solution was added in an amount of 4.2 ml instead of 2.0 ml. The hydrogen peroxide yield obtained by means of the catalyst was 11.4 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 13

A catalyst was prepared as in Example 5, but 7.0 mg of nickel metal instead of iron was used. It was observed that the Ni metal had dissolved before the subsequent catalyst preparation stages. The hydrogen peroxide yield obtained by means of the catalyst was 10.8 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 14

A catalyst was prepared as in Example 13, but nickel was added in an amount of 12.3 mg instead of 7.0 mg, and the reduction was carried out by means of formaldehyde as in Example 6. The hydrogen peroxide yield obtained by means of the catalyst was 11.4 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 15

A catalyst was prepared as in Example 1, but this time two salt solutions were added to the Pd chloride solution: 38.8 ml of an iron chloride solution and 12.8 ml of a nickel chloride solution. The hydrogen peroxide yield obtained by means of the catalyst was 12.3 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 16

A catalyst was prepared as in Example 4, but the additives used were 34.5 ml of an iron chloride solution and 7.1 ml of a nickel chloride solution. A measurement showed that the hydrogen peroxide yield obtained by means of the catalyst was 16.8 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 17

A catalyst was prepared as in Example 1, but the iron and chromium used as additives were added as metals. Iron was added in an amount of 52.5 mg and chromium in an amount of 18.2 mg. The metals were allowed to dissolve in the Pd salt solution before the subsequent preparation stages. A measurement showed that the hydrogen peroxide yield obtained by means of the catalyst was 14.6 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 18

A catalyst was prepared in accordance with Example 4. Iron chloride solution was used in an amount of 33 ml and chromium chloride solution in an amount of 22.1 ml. The hydrogen peroxide yield obtained by means of the catalyst was 12.2 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 19

By dissolving nickel chloride and chromium chloride in water and by adding 2 ml of a strong hydrochloric acid per a one-liter batch, a solution was prepared having a Cr concentration of 3.3 g/l and a Ni concentration of 1.8 g/l. A catalyst was prepared as in Example 1, but the additive metals were batched in the form of the above solution (7 ml) into the palladium chloride solution. The hydrogen peroxide yield obtained by means of the catalyst was 11.0 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 20

A catalyst was prepared in accordance with Example 4, except that the adding of the iron solution was omitted and

20.6 ml of a chromium chloride solution and 6.9 ml of a nickel chloride solution were added in its stead. The hydrogen peroxide yield obtained by means of the catalyst was 13.1 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 21

A catalyst was prepared as in Example 1, but this time three metal components were added. The metal components were added as chloride solutions according to Example 1: iron solution in an amount of 19.4 ml, chromium solution 14.3 ml, and nickel solution 21 ml. The hydrogen peroxide yield measured for the catalyst was 12.0 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 22

Used palladium catalyst was dissolved as in Example 5. The preparation was in other respects in accordance with Example 1. The iron, chromium and nickel were added as solutions in accordance with Example 1: iron solution in an amount of 33.8 ml, chromium solution 22.1 ml, and nickel solution 7.1 ml. The hydrogen peroxide yield measured for the catalyst was 27.5 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 23

Used palladium catalyst was dissolved as in Experiment 4. The preparation was in other respects as in Example 1. Iron, chromium and nickel were added in the form of solutions according to Example 1. Iron solution was added in an amount of 19.4 ml, chromium solution 12.4 ml, and nickel solution 3.9 ml. The hydrogen peroxide yield measured for the catalyst was 15.0 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 24

A catalyst was prepared as in Example 6, except that chromium chloride solution was now added in an amount of 7.3 ml, and additionally iron chloride solution according to Example 1 was added in an amount of 12.2 ml and nickel chloride solution in an amount of 2.8 ml. The hydrogen peroxide yield obtained for the catalyst in a test measurement was 14.2 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 25

A catalyst was prepared as in Example 1. Iron was added as a metal in an amount of 6.1 g, deviating from Example 1, and the other components, chromium and nickel, were added in the form of chloride solutions in accordance with Example 1. The chromium-containing solution was added in an amount of 1.3 ml, and the nickel-containing solution in an amount of 0.7 ml. The hydrogen peroxide yield measured for the catalyst was 12.5 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 26

A catalyst was prepared in accordance with Example 4. The iron chloride solution according to Example 1 was now added in an amount of 3.3 ml and the chromium and nickel solutions each in an amount of 4 ml, diluted 1:10 from the solutions of Example 1. The hydrogen peroxide yield measured for the catalyst was 13.1 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 27

From iron chloride, chromium chloride and nickel chloride 1 liter of a solution was prepared which contained 2.7 g Fe, 1.7 g Cr, and 0.6 g Ni. That the solution remained in the form of a solution was ensured by making the solution acid by means of 2 ml of a strong, 33-percent hydrochloric acid. A catalyst was prepared in accordance with Example 4. The additive metals were batched by adding the above solution in an amount of 10 ml. The hydrogen peroxide yield measured for the catalyst was 22.4 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

#### Example 28

A catalyst was prepared from a palladium chloride solution as in Example 1. Iron in an amount of 23.7 mg was added in metal form to the solution, the chromium and nickel were added as chloride solutions according Example 1. Chromium solution was added in an amount of 10.3 ml and nickel solution in an amount of 4.8 ml. The hydrogen peroxide yield measured for the catalyst was 9.1 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 29

A catalyst was prepared as in Example 6, but the iron, chromium and nickel were added in solid form, as chloride salts containing six molecules of water of crystallization: ferrichloride 104.5 mg, chromium(III) chloride 34.4 mg, and nickel(II) chloride 16.5 mg. The hydrogen peroxide yield measured for the catalyst was 11.0 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 30

A catalyst was prepared as in Example 5. Iron in metal form was this time added in an amount of 28.8 mg, chromium was added as chromium(III) chloride (cf. Example 29) 65 mg, and nickel in metal form 5.7 mg. The hydrogen peroxide yield measured for the catalyst was 10.8 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 31

A catalyst was prepared as in Example 1. The amount of iron-containing solution added was 3.6 ml, of chromium-containing solution 13.4 ml, and of nickel-containing solution 48 ml. The hydrogen peroxide yield measured for the catalyst was 14.8 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 32

From FeCl<sub>3</sub> · 6H<sub>2</sub>O, CrCl<sub>3</sub> · 6H<sub>2</sub>O and NiCl<sub>2</sub> · 6H<sub>2</sub>O, one liter of a solution was prepared into which was weighed 83.6 g of the iron compound, 21.0 g of the chromium salt, and 8.7 g of the nickel compound. A catalyst was prepared according to Example 1, but the additive component was batched by adding 10 ml of the above solution. The hydrogen peroxide yield measured for the catalyst was 19.6 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 33

540 ml of the palladium chloride solution according to Example 1 was taken, and 0.6 g of platinum was added to it as a H<sub>2</sub>PtCl<sub>6</sub> · 6H<sub>2</sub>O compound in an amount of 1.6 g. In other respects the catalyst was prepared as in Example 1. The iron, chromium and nickel were added as solutions according to Example 1, iron-containing solution in an amount of 8.6 ml, chromium-containing solution 5.5 ml, and nickel-containing solution 6.5 ml. The hydrogen peroxide yield measured for the catalyst was 14.8 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

Example 34

A catalyst was prepared as in Example 33. To the palladium-platinum chloride solution was added 10.8 ml of a solution which had been prepared as in Example 1 but had a chromium concentration 10 times that in the chromium solution of Example 1. The hydrogen peroxide yield measured for the catalyst was 15.1 g H<sub>2</sub>O<sub>2</sub>/g catalyst.

To a palladium-containing acid solution (Pd 2+) was added one or more transition-group metals as salt solutions. The pH of the solution was raised to approximately three by means of lye, before the adding (1.5 x the stoichiometric amount in proportion to the palladium) of the formic acid which was used as the reducing agent. When the pH was raised by means of lye to approximately 9, the Pd was reduced and the additive metal coprecipitated. The catalyst was prepared under a shield gas of nitrogen. The catalyst was washed with water and was transferred from the aqueous medium to the working solution or to the solvent part of the working solution before the testing. The catalyst was tested as described above. The results are shown in the following table.

Example No.	Metal concentration in the Pd catalyst							H2O2 yield g/g cat.
	Ti ppm	Zr ppm	Al ppm	Ce ppm	La ppm	Mn ppm	Co ppm	
35	40							7.81
36	60							11.16
37	490							13.95
38	1100							14.32
39	3200							17.48
40	5650							19.53
41	8900							26.04
42	14800							18.60
43		320						9.30
44		350						11.16
45		420						12.65
46		850						11.72
47		2100						13.76
48		5700						16.55
49		11000						25.67
50		19000						26.04
51			< 400					7.81



5	52			770					13.58
	53			2200					19.72
	54			3700					12.09
10	55			6100					11.53
	56			13800					21.20
	57				< 10				7.81
15	58				100				11.35
	59				270				9.11
	60				560				7.81
20	61				1950				8.74
	62				3000				13.39
25	63					90			6.51
	64					300			8.56
	65					700			9.49
30	66					2900			9.30
	67					4800			9.67
35	68						550		7.44
	69						1100		6.88
	70						3500		6.88
40	71						6300		6.88
	72							640	7.63
45	73							1300	12.09
	74							3800	23.62
	75							6500	26.04
50	76	1250	1100						5.39
	77	3800	2900						5.39

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5	78	1100		820				8.00
	79	3300		3500				20.83
	80	4800		6100				15.62
10	81	1200			2200			10.23
	82	3500			4800			17.67
	83	5700			10000			14.88
15	84		1000	< 400				9.67
	85		3300	4300				14.88
20	86		640		690			10.60
	87		2300		2700			16.18
	88		10000		7700			20.83
25	89			< 400	420			8.18
	90			3200	2300			21.95
30	91			2700	4450			15.81
	92			2000		1100		14.14
	93			1500		2700		23.25
35	94			2700		4700		23.81
	95	1100	1200	< 400				13.02
40	96	3700	3200	1900				16.93
	97	6500	5300	4300				24.55
45	98	7200		1900		15600		25.11

The method according to the invention is not limited to the embodiment examples presented above; it can be varied within the scope defined by the accompanying patent claims. The essential idea is that the adding of the transition metal is carried out in such a way that the transition metal will become mixed with the noble metal.

#### Claims

1. A hydrogenation catalyst for use in the preparation of hydrogen peroxide by the anthraquinone process, the catalyst comprising finely-grained metal particles which in the main consist of one or more noble metals of the platinum group, more than 50% by weight of the noble metal being palladium, characterised in that (i) the particles contain at least one transition metal or aluminium in addition to the said noble metal; and (ii) the amount of the transition metal, when only one such metal is present, the amount of each transition metal, when more than one such metal

3. Hydrierkatalysator nach Anspruch 1, dadurch gekennzeichnet, daß das Edelmetall Palladium und Platin ist.
4. Hydrierkatalysator nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß das Übergangsmetall bzw. die Übergangsmetalle aus Eisen, Chrom, Nickel, Titan, Zirkonium, Cerium, Lanthan, Mangan und Kobalt ausgewählt sind.
5. Verfahren zur Herstellung eines Hydrierkatalysators, der zur Herstellung von Wasserstoffperoxid durch das Anthrachinon-Verfahren vorgesehen ist, wobei bei dem Verfahren suspensible, feinkörnige Metallpartikel gebildet werden, die in der Hauptsache aus Edelmetall sind, das aus einem oder mehreren Metallen der Platinreihe besteht, und wobei über 50 Gew.-% des Edelmetalls Palladium ist, dadurch gekennzeichnet, daß in den gebildeten Partikeln zusätzlich zu dem Edelmetall zumindest ein Übergangsmetall oder Aluminium enthalten ist, und der Anteil des Übergangsmetalls, wenn nur ein solches Metall vorhanden ist, der Anteil von jedem Übergangsmetall, wenn mehr als ein solches Metall vorhanden ist, und der Anteil des Aluminiums, sofern vorhanden, jeweils 0,01 - 3,0 Gew.-% der Menge des Edelmetalls beträgt.
6. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß das Edelmetall ausschließlich Palladium ist.
7. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß das Edelmetall Palladium und Platin ist.
8. Verfahren nach einem der Ansprüche 5 bis 7, dadurch gekennzeichnet, daß das Übergangsmetall bzw. die Übergangsmetalle aus Eisen, Chrom, Nickel, Titan, Zirkonium, Cerium, Lanthan, Mangan und Kobalt ausgewählt sind.
9. Verfahren nach einem der Ansprüche 5 bis 8, dadurch gekennzeichnet, daß das Übergangsmetall oder das Aluminium oder die Übergangsmetalle mit oder ohne Aluminium in einer Edelmetalllösung eingebracht werden, aus der die Metalle als feinkörnige Partikel ausgefällt werden.
10. Verfahren nach Anspruch 9, dadurch gekennzeichnet, daß das Übergangsmetall oder das Aluminium oder die Übergangsmetalle mit oder ohne Aluminium der Edelmetalllösung in der Form eines Metalls, eines Metallsalzes oder einer Metallsalzlösung zugefügt werden.
11. Verfahren zum Hydrieren von Anthrachinon oder einem Derivat davon zu dem entsprechenden Hydrochinon als Teil der Wasserstoffperoxid-Herstellung durch das Anthrachinon-Verfahren, wobei bei dem Verfahren das Hydrieren in einer organischen Lösung mittels eines feinkörnigen Metall-Katalysators durchgeführt wird, dadurch gekennzeichnet, daß die verwendeten Katalysator-Partikel in der Hauptsache aus Edelmetall sind, das aus einem oder mehreren Metallen der Platinreihe besteht, daß über 50 Gew.-% des Edelmetalls Palladium ist, und daß die Partikeln zusätzlich zu dem Edelmetall zumindest ein Übergangsmetall oder Aluminium enthalten, und der Anteil des Übergangsmetalls, wenn nur ein solches Metall vorhanden ist, der Anteil von jedem Übergangsmetall, wenn mehr als ein solches Metall vorhanden ist, und der Anteil des Aluminiums, sofern vorhanden, jeweils 0,01 - 3,0 Gew.-% der Menge des Edelmetalls beträgt.
12. Verfahren nach Anspruch 11, dadurch gekennzeichnet, daß das Übergangsmetall oder die Übergangsmetalle aus Eisen, Chrom, Nickel, Titan, Zirkonium, Cerium, Lanthan, Mangan und Kobalt ausgewählt sind.

#### Revendications

1. Un catalyseur d'hydrogénation pour servir dans la préparation de peroxyde d'hydrogène par le procédé à l'antraquinone, le catalyseur comprenant des particules de métal à grains fins qui consistent en général en un ou plusieurs métaux nobles du groupe du platine plus de 50% en poids du métal noble étant constitués par du palladium, caractérisé en ce que (i) les particules contiennent au moins un métal de transition ou de l'aluminium en plus de ce métal noble; et (ii) la quantité du métal de transition, lorsqu'un seul métal de ce type est présent, la quantité de chaque métal de transition, lorsque plus d'un tel métal est présent, et la quantité d'aluminium lorsqu'il est présent, étant chacune de 0,01 à 3,0% en poids par rapport à la quantité du métal noble.
2. Un catalyseur d'hydrogénation suivant la revendication 1, caractérisé en ce que le métal noble consiste uniquement en palladium.
3. Un catalyseur d'hydrogénation suivant la revendication 1, caractérisé en ce que le métal noble est constitué de palladium et de platine.

is present, and the amount of aluminium when present, each being 0.01-3.0% by weight of the amount of the noble metal.

2. A hydrogenation catalyst according to claim 1, characterized in that the noble metal consists solely of palladium.
3. A hydrogenation catalyst according to claim 1, characterized in that the noble metal is made up of palladium and platinum.
4. A hydrogenation catalyst according to any of the above claims, characterized in that the transition metal has or the transition metals have been selected from among iron, chromium, nickel, titanium, zirconium, cerium, lanthanum, manganese, and cobalt.
5. A method for the preparation of a hydrogenation catalyst intended for the production of hydrogen peroxide by the anthraquinone process, in which method suspensible, finely-grained metal particles are formed which are in the main noble metal made up of one or more metals of the platinum group, over 50% by weight of the noble metal being palladium, characterized in that, in addition to the said noble metal, at least one transition metal or aluminium is incorporated into the particles formed, the amount of the transition metal, when only one such metal is present, the amount of each transition metal, when more than one such metal is present, and the amount of aluminium when present, each being being 0.01 to 3.0% by weight of the amount of the noble metal.
6. A method according to claim 5, characterized in that the noble metal is made up solely of palladium.
7. A method according to claim 5, characterized in that the noble metal is made up of palladium and platinum.
8. A method according to any one of claims 5 to 7, characterized in that the transition metal is or the transition metals are selected from among iron, chromium, nickel, titanium, zirconium, cerium, lanthanum, manganese and cobalt.
9. A method according to any one of claims 5 to 8, characterized in that the transition metal or aluminum is or the transition metals with or without aluminium are introduced into a noble metal solution, from which the metals are precipitated as finely-grained particles.
10. A method according to claim 9, characterized in that the transition metal or aluminium is or the transition metals with or without aluminium are added in the form of a metal, a metal salt, or a metal salt solution to the noble metal solution.
11. A method for the hydrogenation of anthraquinone or a derivative thereof to the corresponding hydroquinone as part of hydrogen peroxide production by the anthraquinone method, in which method the hydrogenation is carried out in an organic solvent by means of a finely-grained metal catalyst, characterized in that catalyst particles are used which are in the main of a noble metal made up of one or more metals of the platinum group, more than 50% by weight of the noble metal being palladium, and which particles contain at least one transition metal or aluminium in addition to the said noble metal, the amount of the transition metal, when only one such metal is present, the amount of each transition metal, when more than one such metal is present, and the amount of aluminium when present, each being 0.01 to 3.0% by weight of the amount of the noble metal.
12. A method according to claim 11, characterized in that the transition metal has or the transition metals have been selected from among iron, chromium, nickel, titanium, zirconium, cerium, lanthanum, manganese and cobalt.

#### Patentansprüche

1. Hydrierkatalysator zur Verwendung bei der Herstellung von Wasserstoffperoxid durch das Anthrachinon-Verfahren, wobei der Katalysator feinkörnige Metallpartikel enthält, die in der Hauptsache ein oder mehrere Edelmetalle der Platinreihe enthalten, und wobei mehr als 50 Gew.-% des Edelmetalls Palladium ist, dadurch gekennzeichnet, daß (i) die Partikel zusätzlich zu dem Edelmetall zumindest ein Übergangsmetall oder Aluminium enthalten; und (ii) der Anteil des Übergangsmetalls, wenn nur ein solches Metall vorhanden ist, der Anteil von jedem Übergangsmetall, wenn mehr als ein solches Metall vorhanden ist, und der Anteil des Aluminiums, sofern vorhanden, jeweils 0,01 - 3,0 Gew.-% der Menge des Edelmetalls beträgt.
2. Hydrierkatalysator nach Anspruch 1, dadurch gekennzeichnet, daß das Edelmetall ausschließlich Palladium ist.

4. Un catalyseur d'hydrogénation suivant l'une quelconque des revendications précédentes, caractérisé en ce que le métal de transition ou les métaux de transition sont choisis parmi le fer, le chrome, le nickel, le titane, le zirconium, le cérium, le lanthane, le manganèse et le cobalt.
- 5 5. Un procédé de préparation d'un catalyseur d'hydrogénation destiné à la production de peroxyde d'hydrogène par le procédé à l'anthraquinone, dans lequel procédé il est formé des particules de métal à grains fins pouvant être mises en suspension, qui consistent en général en un métal noble constitué d'un ou plusieurs métaux du groupe du platine, plus de 50% en poids du métal noble étant constitués par du palladium; caractérisé en ce qu'en plus de ce métal noble au moins un métal de transition ou de l'aluminium est incorporé dans les particules formées, la
- 10 quantité du métal de transition, lorsqu'un seul métal de ce type est présent, la quantité de chaque métal de transition, lorsque plus d'un tel métal est présent, et la quantité d'aluminium lorsqu'il est présent, étant chacune de 0,01 à 3,0% en poids par rapport à la quantité du métal noble.
6. Un procédé suivant la revendication 5, caractérisé en ce que le métal noble consiste uniquement en palladium.
- 15 7. Un procédé suivant la revendication 5, caractérisé en ce que le métal noble est constitué de palladium et de platine.
8. Un procédé suivant l'une quelconque des revendications 5 à 7, caractérisé en ce que le métal de transition ou les métaux de transition sont choisis parmi le fer, le chrome, le nickel, le titane, le zirconium, le cérium, le lanthane, le
- 20 manganèse et le cobalt.
9. Un procédé suivant l'une quelconque des revendications 5 à 8, caractérisé en ce que le métal de transition ou l'aluminium ou les métaux de transition avec ou sans aluminium sont introduits dans une solution de métal noble, à partir de laquelle les métaux sont précipités sous forme de particules à grains fins.
- 25 10. Un procédé suivant la revendication 9, caractérisé en ce que le métal de transition ou l'aluminium ou les métaux de transition avec ou sans aluminium sont ajoutés sous la forme d'un métal, d'un sel métallique ou d'une solution de sel métallique à une solution de métal noble.
- 30 11. Un procédé d'hydrogénation de l'anthraquinone ou d'un dérivé de celle-ci en l'hydroquinone correspondante en tant que partie de la production de peroxyde d'hydrogène par le procédé à l'anthraquinone, dans lequel procédé l'hydrogénation est conduite dans un solvant organique avec un catalyseur à métal à grains fins, caractérisé en ce qu'il est utilisé des particules de catalyseur qui consistent en général en un métal noble constitué d'un ou plusieurs
- 35 métaux nobles du groupe du platine, plus de 50% en poids du métal noble étant constitués par du palladium, et lesquelles particules contiennent au moins un métal de transition ou de l'aluminium en plus de ce métal noble, la quantité du métal de transition, lorsqu'un seul métal de ce type est présent, la quantité de chaque métal de transition, lorsque plus d'un tel métal est présent, et la quantité d'aluminium lorsqu'il est présent, étant chacune de 0,01 à 3,0% en poids par rapport à la quantité du métal noble.
- 40 12. Un procédé suivant la revendication 11, caractérisé en ce que le métal de transition ou les métaux de transition sont choisis parmi le fer, le chrome, le nickel, le titane, le zirconium, le cérium, le lanthane, le manganèse et le cobalt.